Soil Salinity and Drainage Problems

· Causes
· Effects
· Management

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HOW TO PREVENT AND CONTROL SALINITY AND DRAINAGE PROBLEMS

Soil salinity and drainage problems can be minimized by:

- Carefully selecting lands to be irrigated, especially for type of soil and topography.
- Providing adequate surface drainage.
- Leveling the land and irrigating properly to avoid excessive use of water.
- Using proper cultural methods and special treatments such as manure and organic matter to improve the physical condition of the soil.
- Avoiding summerfallow.
- Growing salt-tolerant crops and following fertilizer recommendations.
- Avoiding deep cultivation.

Reclamation of salinized land can be achieved by:

- Controlling the sources of excess water.
- Lining canals and ditches to reduce seepage.
- Providing artificial drainage to ensure that the water table remains below the root zone.
- Leaching the salts periodically where the subsurface drainage is adequate.

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Cover Picture. The white scourge. Accumulations of surface salt caused by a high water table take many acres of land out of production each year.

SOIL SALINITY AND DRAINAGE PROBLEMS

Causes, Effects, Management

R. A. MILNE and E. RAPP
Research Station, Lethbridge, Alberta

Soil salinity problems are caused mainly by inadequate drainage. Salt-affected soils are those that contain enough water-soluble salts to affect crop growth. They occur mainly on irrigated land, but they may be a problem in nonirrigated areas. Salts and waterlogging affect about one-tenth of our irrigated lands. Problems of salinity and drainage have increased as a result of mismanagement and intensive irrigation. Some lands have become salty under irrigation because of the chemical and physical characteristics of the soil. These are lands that should never have been included in irrigation projects. On dry lands in Western Canada, most salt problems have developed because of the semiarid climate, type of soil deposition, and type of topography.

Drainage of irrigated lands removes the excess water and salts. Excess water becomes a problem when it interferes with plant growth, land preparation, and other farming operations. Much of the excess water is often removed naturally by surface runoff, deep percolation, evaporation, and transpiration. When the removal is impeded, either on the surface or in the subsoil, salinity and drainage problems develop and you must then provide artificial drainage. The groundwater often contains enough soluble salts to permit toxic accumulation at or near the ground surface. The problem may become serious if the water table rises as a result of excess irrigation, seepage from canals or higher land, or artesian pressure. Costly drainage measures may then be needed to remove salts from the plant root zone.

DESCRIPTION OF SALT-AFFECTED SOILS

The main salts in Western Canadian soils are calcium sulfate (gypsum), magnesium sulfate (Epsom salts), sodium sulfate (Glauber's salt), and potassium sulfate. Small amounts of bicarbonates and chlorides are usually combined with these salts. There are several types of salt-affected soils.

Saline soils are the most common type and are usually the easiest to reclaim. They are neutral to slightly alkaline. Their structure is generally good, and their permeability to water and tillage characteristics are like those of nonsaline soils. Saline soils are recognized by spotty growth of crops and often by white crusts of salt on the soil surface (Figure 1). Plants affected by soil salinity often have a blue-green tinge.

Saline-sodic soils have a high sodium absorption ratio (SAR) and high total salts in the soil solution. They are alkaline and are the most common

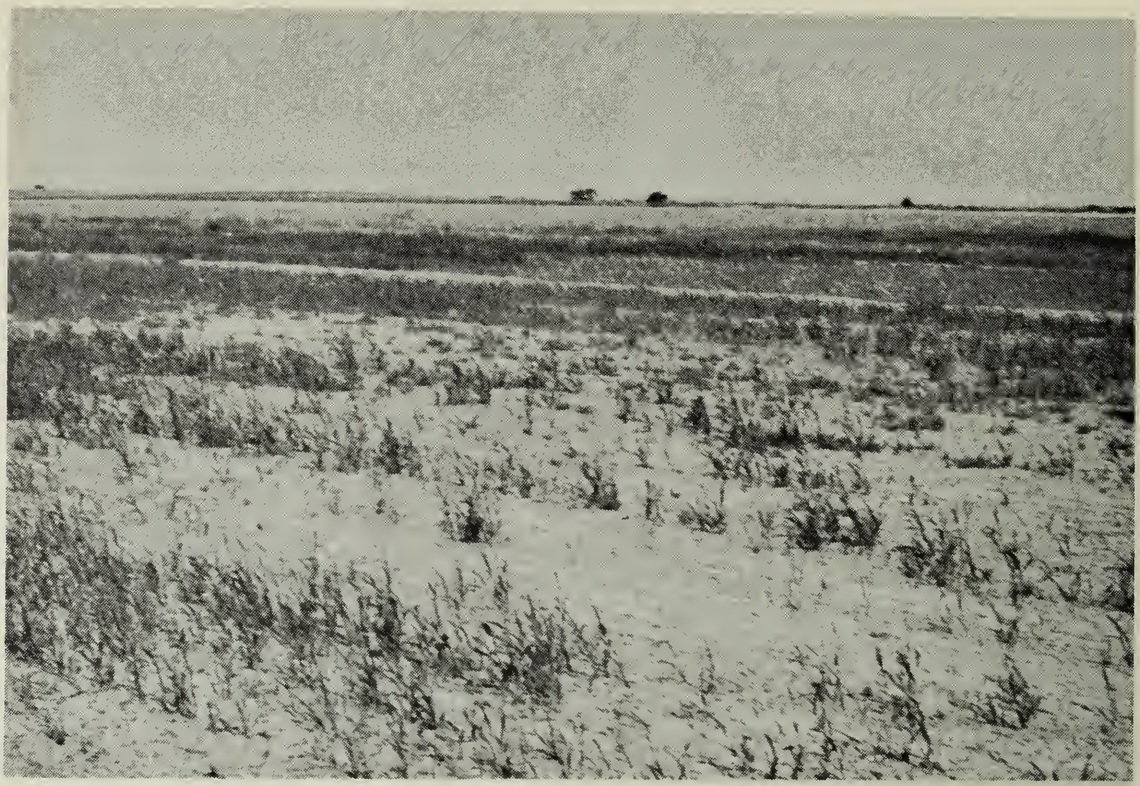

Figure 1. Sparse growth due to a moderate amount of salts. The area was later reclaimed by pump drainage and leaching.

Figure 2. Severely affected saline-sodic area. Growth is mainly salt-tolerant weeds.

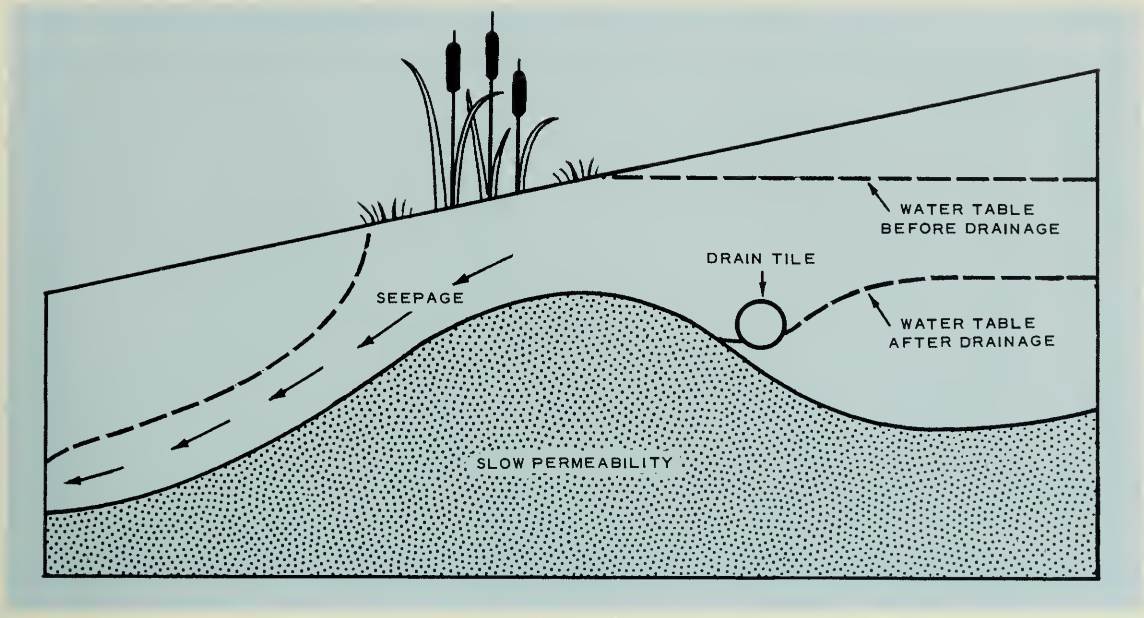

Figure 3. Lateral seepage above a slowly permeable subsoil.

where salt effects are serious (Figure 2). In Western Canada, leaching after drainage does not puddle these soils, and thus permeability to water is maintained. The inherently high content of lime and gypsum in the subsoil prevents the sodium from causing the clay particles to disperse.

Sodic soils have a high SAR, a low salt content, and a high pH. They are usually known as 'blow-out' or solonetzic soils. Their structure is poor; they are underlain with a rather impermeable hardpan. There are millions of acres of sodic soils in Western Canada, generally mixed with nonsodic soils. Their effect on productivity depends on how much of the soil complex they make up.

Calcium carbonate (lime) is often present near the soil surface and exposed on knolls. It is not harmful as a salt, but it may affect the availability of some nutrients to plants.

On dry land, salt-affected areas develop in some years and tend to disappear in others. During wet periods the water table may rise and cause the salinity to increase. During dry periods the water table lowers and movement of salts to the surface stops. Any rain that falls tends to leach the salts downward. The effect of the salts is seen in crop response, but the amount is determined only by a soil test.

CAUSES OF SOIL SALINITY

Problems of soil salinity arise from an excess of salts in the plant root zone. The cause is almost always a high water table. Salt-affected areas often result from lateral flow of salt-laden water below ground surface; the water deposits salts on the surface of sloping lands or in depressions. This movement, or seepage, usually occurs where permeable soil (sand or gravel) overlies impermeable material (clay or bedrock) in the subsurface. It occurs on both irrigated and nonirrigated lands (Figure 3).

When the water table is less than 5 feet below ground surface, water moves upward to the surface by capillarity. This action is greater in fine-

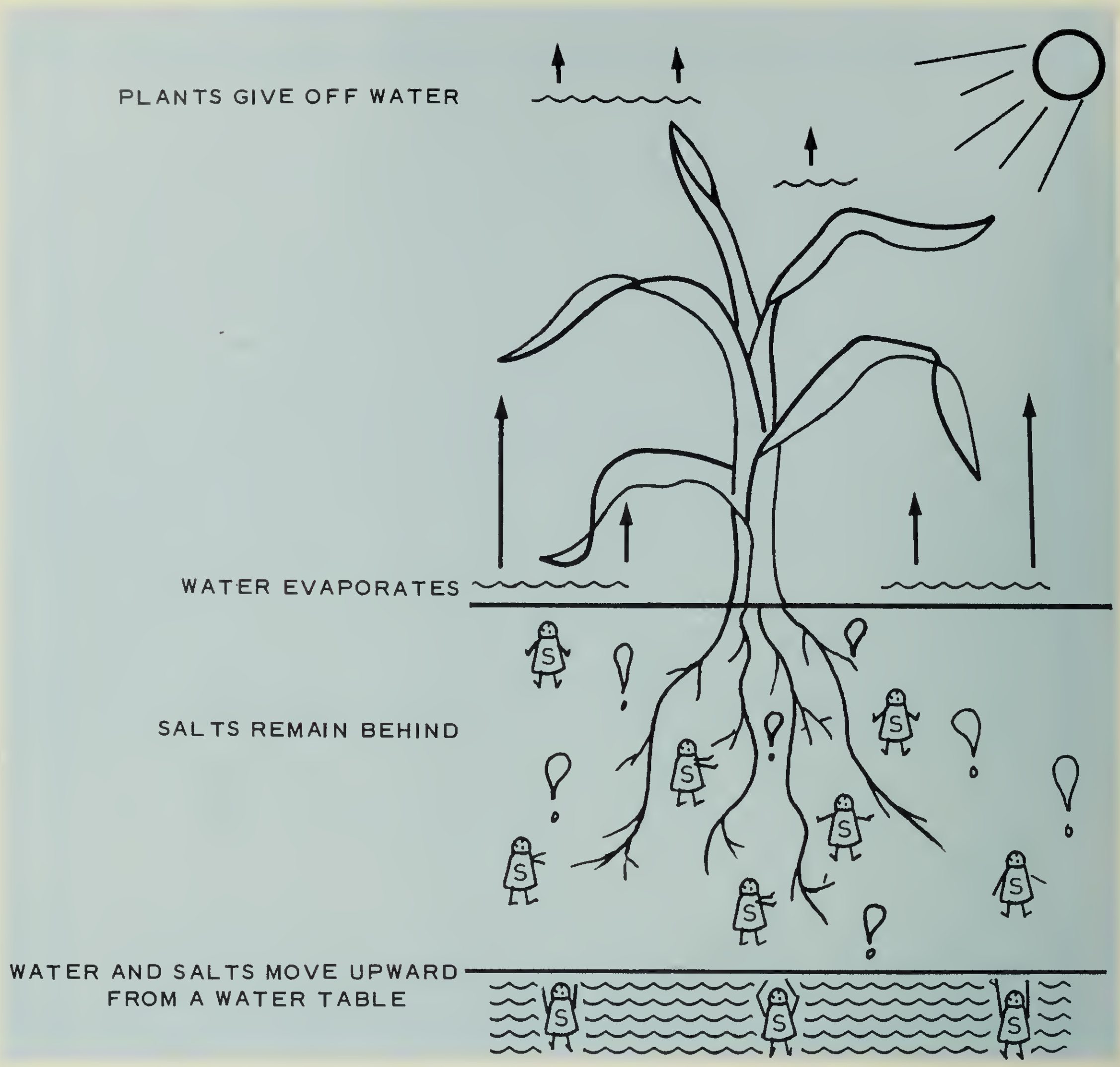

Figure 4. Salts in soil water move to the root zone from a water table by capillary action.

textured soils (clay loam, loam) than in coarse-textured soils (sandy loam, loamy sand). As the roots draw water from the soil around them, more water carrying salts in solution moves up to replace it. Thus salts tend to concentrate in the root zone (Figure 4).

Often, in well-drained irrigated soils, insufficient water is applied to leach soluble salts from surface horizons. Thus salts deposited by the water accumulate in the root zone. Most river waters are low in salts, but they often add salts to the soil when drainage is inadequate. Water from wells or natural ponds often contains harmful amounts of salts, particularly of sodium, and it should be tested for irrigation use.

On a number of irrigation projects, most of the salts originally present in the upper 6 feet of soil have moved downward after about 5 years of irrigation. This is particularly true in soils where the SAR is low. Where the SAR in the original soils is high, the lands have often become salt-affected and waterlogged. Many saline-sodic soils are in this category. As a result of research, lands for irrigation are now being selected carefully. A complete soil salinity and drainage survey is required before the land is irrigated.

EFFECTS OF EXCESS SALTS AND WATER ON PLANTS

The more salts there are in the soil water, the harder it is for the plants to take up enough water. Also, very high salt levels are toxic to plants. Salts in the soil also remove water from the plant roots by plasmolysis, causing their cells to collapse. The presence of some salts reduces the availability of certain plant nutrients. Salts have also been shown to reduce the activity of soil microorganisms, which in turn affects the availability of nutrients to plants and other factors such as soil structure.

Plants may grow well in moderately saline soil when it is high in moisture, because the soil solution then is diluted. However, plants may lack enough water and be injured when the soil moisture becomes less and the salt concentration increases. When water is added to sodic soils, they often puddle (disperse) and their infiltration rate and aeration are impaired. Very often these soils crack when dry, and it is hard to establish stands of forage and cereals on them. A given amount of salt is more injurious in a sandy soil than the same amount in a clay or loam soil.

In most soils there is a permanent level of free water, the upper surface of which is known as the water table. Its depth depends mainly on the soil texture and the depth to an impermeable barrier. It also varies with natural or artificial additions or depletions of groundwater. Drainage removes only water that is free to move under the influence of gravity. This water is superfluous and is not available to plants.

Free subsoil water often makes land wholly or partly unproductive, especially where there is a general upward movement of soluble salts. The excess water affects crop production because the roots may be injured by the lack of aeration and by the excess soluble salts. The high salinity is more serious because remedies are more costly.

SALT TOLERANCE OF CROPS

If you suspect that salt is injuring your crops, have the soil tested for total salt content. Soil samples should represent the area concerned. Since crop growth is a useful guide, you should sample at locations showing no growth, sparse, and adequate growth. Take samples at each 6-inch depth down to 2 feet. For most purposes, the salinity of the soil is determined from a saturation extract of the soil. It is measured as the ability of the extract to conduct an electric current and is expressed as millimhos per centimeter at 25°C. You may have soil salinity tests made in provincial soil testing laboratories. They are often made in conjunction with fertility tests, which are necessary in planning cropping and management practices for salt-affected lands. A plant that is highly resistant to drought is usually salt-tolerant. The salt tolerance of the main field, forage, and vegetable crops is given in Table 1. Tolerance of crops to salt at time of germination sometimes differs from that of established crops (Table 2).

Field Crops

None of the common field crops grow well on strongly saline soils. But some of them withstand moderate levels of soil salinity. Barley is shown to have the greatest tolerance. Most saline areas tend also to be wet, a condition to which barley is sensitive. Sugar beets are fairly tolerant once the

TABLE 1. TOLERANCE[1] OF CROPS TO SALTS

Low tolerance 0-4 mmhos/cm	Moderate tolerance 4-8 mmhos/cm	High tolerance 8-15 mmhos/cm
	Field Crops	
Field beans	Sunflowers	Barley
Soybeans	Flax	Rape
Peas	Corn	Sugar beets
	Wheat	
	Oats	
	Rye	
	Sorghum	
	Forage Crops	
Red clover	Alfalfa	Tall wheatgrass
White Dutch clover	Orchardgrass	Tall fescue
Alsike clover	Bromegrass	Russian wild ryegrass
Timothy	Reed canarygrass	Slender wheatgrass
Red top	Pubescent wheatgrass	Birdsfoot trefoil
		Sweet clover
		Crested wheatgrass
	Vegetables	
Beans	Tomatoes	Beets
Celery	Lettuce	Spinach
Radishes	Broccoli	Asparagus
Cucumber	Potatoes	
Corn	Peppers	

[1] Based on late seedling stage onward.

TABLE 2. TOLERANCE OF CROPS TO SALTS AT TWO STAGES OF GROWTH

Crop	Germination stage	Established stage
Barley	Very good	Good
Rye	Good	Poor
Corn	Good	Poor
Wheat	Fairly good	Fair
Alfalfa	Poor	Good
Sugar beets	Very poor	Good
Beans	Very poor	Very poor

plants are well established. Rye, wheat, oats, and flax are moderately tolerant provided that fertility levels are suitable and adequate moisture is available during germination. Beans and peas are very sensitive to soil salinity. For some crops, some varieties are more salt-tolerant than others.

Forage Crops

Forage crops tend to tolerate salt better than most cereals. Since most are perennials, they shade the soil longer than cereals do. The shade reduces

evaporation from the soil surface. The fibrous roots of forage crops improve the physical condition of the soil because they add organic matter to it. Alfalfa is one of the more tolerant forage crops and removes a considerable amount of water from the soil. Grasses are fairly tolerant to herbicides so weeds can be controlled readily. Unfortunately, grasses that are highly tolerant to salt are not as palatable as others that are not tolerant. But with proper management they produce satisfactory hay, seed, and grazing. A suitable grass mixture for highly salted lands is 10 pounds of tall wheatgrass and 6 pounds of tall fescue per acre. For irrigated lands moderately affected by salt, the following mixture is suitable:

Grass or legume	*Pounds per acre*
Tall wheatgrass	6
Slender wheatgrass	4
Reed canarygrass	4
Yellow sweet clover	2
Tall fescue	2

Seed about ½ inch deep with a press drill. Drill half the seed in one direction and the other half in a crosswise direction, packing well. You may also sow a companion crop of oats at half the regular rate. Seed between the middle of August and the middle of September. Use frequent light applications of water until the stand is established.

On many nonirrigated areas Russian wild ryegrass has shown considerable tolerance to moderate salinity levels. But most of the other salt-tolerant grasses may be used, preferably in a mixture. Because moisture is a limiting factor, seed in the fall to take advantage of the moisture provided by melting snow early in the spring, when the temperature of the soil is also favorable to giving the grass a good start. Soil tests will determine what forage to use if you are in doubt.

Fruit and Tree Crops

Fruit crops are more sensitive to salinity than field crops are. The tolerance differs greatly with variety so it is difficult to suggest their tolerance as a group. Tree crops are also sensitive to salts, especially seedlings and transplants of evergreen and deciduous trees (Figure 5). Even small amounts of salts in the soil, giving conductivity readings of as low as 3 millimhos per centimeter, have affected the survival of evergreen transplants. Because trees are extremely sensitive, plant them only in areas that are comparatively salt-free. If there is doubt, have soil tests made.

MANAGING SALT-AFFECTED LANDS

In the most severely affected lands high water tables have likely developed as a result of seepage, excess irrigation, and other mismanagement. Before you can reclaim these lands you must find the source of the excess water and salts. To reclaim the land completely, a drainage system is needed.

Lands slightly to moderately affected include those being reclaimed by drainage, many nonirrigated salt-affected areas, and the "blow-out" or solonetzic soils. Drainage may not be urgently needed or may not be practical or feasible.

Figure 5. Evergreen transplants stunted because of salinity. The area was later drained with tile drains and leached. Growth is now normal.

To minimize or correct the salinity problem, a number of management practices are recommended:

- Use salt-tolerant crops. This is probably the best method of managing salt-affected lands. Salty areas are often wet. Keep this in mind when selecting crops. Mixtures of forage crops are better than single varieties on salt-affected lands.
- Improve surface drainage. Leveling the land prevents the accumulation of water in low areas and thus minimizes waterlogging.
- Manage water properly. Where drainage is adequate, apply enough water to leach salts downward. On many dryland areas trapping the snow and rain helps to leach surface salts.
- Apply barnyard manure to saline or sodic spots. Plow down green manure such as sweet clover and alfalfa. They add organic matter, which increases the water-holding capacity of the soil and reduces salt effects.
- Avoid deep tillage. Soluble salts are usually concentrated a few inches below the soil surface.
- Seed when moisture conditions are most suitable, especially in non-irrigated areas. Usually, fall seeding is recommended to take advantage of spring moisture. Under irrigation, frequent light applications of water (preferably by sprinkler) help to leach surface salts, allowing germination.
- Avoid summerfallow where possible. Fallow encourages the buildup of a water table since water is being stored. There is often greater runoff, causing accumulation of water in low areas.
- Try different fertilizers. Applications of nitrogen and phosphorus are usually effective if salts are not excessive. Nitrogen fertilizers have been

beneficial on certain solonetzic soils where moisture was adequate. Make soil tests before applying fertilizer.

- Cultivate at the right time. "Blow-out" or solonetzic soils puddle if worked when wet and are difficult to cultivate if too dry. Deep plowing to mix the lime and gypsum with the layers high in sodium has proved beneficial on these soils.
- Chemical amendments such as gypsum, lime, and sulfur, often recommended, have not proved beneficial in prairie areas in Canada. The subsoils contain adequate quantities of these chemicals.

CAUSES OF DRAINAGE PROBLEMS

The main cause of drainage problems in irrigated areas is the application of more water than is needed for crop production. Other causes are seepage from canals and ditches and lateral movement of subsurface water.

Excess Irrigation

When more irrigation water is applied than the crops need, some percolates below the root zone. If downward percolation is restricted, the water table rises and causes salts to move upward. Plant growth may be seriously reduced or the land may even become unproductive. Some percolation below the root zone is desirable to maintain a favorable salt balance in the soil. But continued overuse or waste of irrigation water may necessitate subsurface drainage to remove the excess water and soluble salts. This drainage is expensive, and often impractical where soils below the root zone are relatively impermeable. Drainage problems caused by poor irrigation practices can be eliminated or reduced by planning irrigation systems properly, developing efficient irrigation methods, and applying water efficiently to reduce the need for drainage.

Seepage Losses

Excessive seepage of water from canals and ditches often aggravates drainage and salt problems. Seepage may be reduced or prevented by:

- Locating canals and laterals properly;
- Modernizing the distribution system;
- Avoiding the unnecessary use of water;
- Lining canals and ditches with a thin film or layer of impermeable material where excessive seepage occurs.

Eliminating the source of excess water rather than applying corrective measures is the most logical approach.

Movement of Underground Water

Sometimes water from excess irrigation, precipitation, or canal seepage moves underground and reappears some distance downslope. The accumulation of excess water where the subsoil drainage is restricted invariably results in waterlogging and salinity. Also, the movement of artesian water may develop a high water table and lead to salinity hazards.

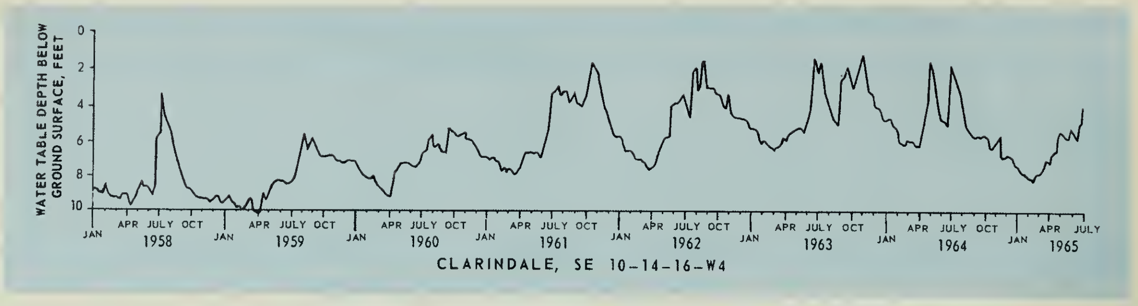

Figure 6. Water-table hydrograph showing the position of the water table and its fluctuations.

DRAINAGE INVESTIGATIONS

Before a drainage problem can be solved, you must study the affected area thoroughly. The solution must be based on conditions prevailing in the area. The condition of the soil surface is a key to many drainage problems. But sometimes the effects of inadequate drainage, such as a gradual decrease in crop production, are not seen so readily. The poor growth may be due to a high water table, salinity in the root zone, or diseases in the plant roots, caused by excess subsurface water.

The four main factors to consider in making a drainage investigation are topography, soils, the slope and nature of the water table, and water source. These factors are so closely related that the correction of one factor seldom alleviates the entire condition. An intelligent analysis of all factors will result in a practical solution. Any existing information should be collected and fully reviewed before proceeding with a detailed field investigation.

Topography

First study the topography of the area by visual field inspection. Aerial maps if available often yield valuable information. But unless the problem can be solved readily, you must make a topographic survey.

Soils

Study the soils to determine the character of the soil profile to a depth of at least 10 feet. Its variation within the problem area should also be studied. The ability of the various subsoil layers to transmit water (hydraulic conductivity) dictates not only the type of drainage system needed but the design as well.

Water Table

Observing the position of the water table and its fluctuations (Figure 6), at least for one irrigation season, will yield valuable information for the design of the drainage system. Auger holes, small cased observation wells, or piezometers are usually used to observe the height of the water table. You should know the direction and velocity of flow. Drainage is often more

effective and costs less if the damaging water is intercepted before it reaches the problem area.

Water Source

A survey of the water source often suggests ways of reducing the flow. When you know the origin of the water, you may also be able to estimate the quantity of water to be drained. The kind of groundwater, whether saline or alkaline, must also be known before the problem can be solved.

DRAINAGE METHODS

In some areas the water table can be lowered by controlling the sources of excess water. This usually means more efficient systems of water conveyance and application to decrease percolation to the groundwater. Improving the natural drainage protects the land from excessive percolation by rains and melting snow and from flood damage. But when control of excess water sources and maintenance of natural drainage systems are impractical and uneconomic, you must provide artificial drainage.

Relief and Interceptor Drains

Excess water may be removed by relief drains that lead the water away from the problem area, or by interceptor drains that collect and divert water before it reaches the area. Open drains, tile drains, or pumped wells may serve either of these purposes. Relief drains are used where the land has little or no slope, whereas interceptor drains are used more often in areas where the topography is irregular.

Location of Drains

In designing a drainage system, it is important to place the drains properly. In general the problem of draining irrigated lands is more one of location than of spacing. In nonuniform soils consider the nature and extent of the subsoil layers. Generally drains should be oriented at right angles to the direction of groundwater flow and, where possible, connect with permeable layers. In soils of alluvial origin the orientation of both permeable and impermeable materials may be such that a few well-placed drains may control the water table better than more drains spaced uniformly.

For perched water tables relief drains are satisfactory, but an interceptor drain may be needed to cut off lateral seepage. Perched water tables may be controlled by reducing seepage from canals, by improving irrigation practices, and by providing adequate surface drainage.

Lateral groundwater flow is influenced by soil stratification and other natural barriers to flow. Interceptor drains may be used to cut off lateral hillside seepage before it reaches the surface. Subsurface soil masses of low permeability, such as clay bars, may cause the water table to remain at a high level. Drains placed just upslope from a subsoil restriction are similarly effective (see Figure 3). An interceptor drain at the toe of the bank may cut off irrigation canal seepage before it reaches the wet area.

TYPES OF DRAINS

A drain provides a flow path of low resistance for the free water in the soil. The type of drain to select depends on the cost of installation and maintenance, the value of the land, and often on personal preferences. Certain features of construction and use of drains are unique to irrigated regions and to the conditions in individual areas.

The main types of drains are open-channel or surface drains, covered or subsurface drains, and pumped wells.

Open Drains

Open-channel or surface drains (drainage ditches) on irrigated lands serve primarily to remove and dispose of waste irrigation water. They are the most economical means of removing large quantities of surface water rapidly. They often minimize the need for costlier subsurface drainage.

Although their primary function is to handle surface drainage, open drains may be used to lower the water table and thus provide internal drainage. Where subsurface drains are not economical or physically feasible, as in heavy clay soils and where the topography is nearly flat, open drains may be the only practical means of draining the land. Where the depth is sufficient and other conditions are suitable, open ditches also serve as outlets for subsurface drainage systems.

One of the main disadvantages of open drains is that they occupy land that might otherwise be farmed. Open ditches across cultivated fields obstruct farming operations. In pastures open drains may be a source of danger to livestock. They are more costly to maintain than closed drains.

Design — The location of natural channels and low areas generally determines the location of an open drain. The location may often be fixed by the canal system and the depth and location of permeable soil layers carrying seepage waters.

In most irrigation districts, a natural channel such as a creek or river becomes the final outlet for the drains. On farms where the quantity of drain water is small, the outlet may be at a higher level than water in the drain ditch. You may then install a sump with a pumping plant to raise the water for discharge into a higher trunk drain.

Construction — Open drains are commonly constructed by use of large power-driven draglines (scraper-bucket excavators) (Figure 7), backhoes, power shovels, or clamshells. Blade graders, elevating graders, scrapers, and bulldozers may also be used. The unit production and cost of each type of equipment varies with the material excavated, the size of equipment, and the size of job. An estimate of cost may be obtained from an experienced local ditching contractor. In Western Canada, the unit cost per cubic yard of excavation is about 20 cents.

Place the excavated material on one or both sides of the open ditch. Where feasible, spread the spoil bank out over adjacent areas and level it. Install enough inlets through the spoil banks to allow surface water to drain from the adjoining land.

Where extremely wet conditions make poor footing for machinery, dynamiting may be used to excavate new ditches. It may also be used to

open silted channels and old ditches. Blasting is hazardous and should only be done by a person qualified to handle explosives.

Maintenance — Drains that become obstructed by brush or weeds or whose banks have sloughed in and are partly filled with silt do not provide efficient drainage. Cleaning out the obstructed drains to their original depth every year or two will prove beneficial.

Machines have been developed for ditch cleaning, but generally the best method is by use of the same machinery used in the original construction. Burning and herbicides are effective in controlling brush and weeds. Sometimes they are more effective than machine cleaning.

Timely preventive measures are often cheaper than corrective measures, and they may delay the need for maintenance. For example, channel erosion may be controlled either by providing mechanical drops in the channel or by reshaping the channel to reduce the velocity of flow. Similarly, bank erosion may be controlled either by making the side slopes flatter or by seeding to a suitable grass. On curves, continuous riprapping with rocks or stones prevents erosion.

Subsurface Drains

Subsurface drains are used to remove excess water from the soil. They are generally tile drains of clay or concrete pipe butted together to form a continuous buried line. Water enters through the unsealed joints or spaces between the tiles. In irrigated areas tile lines are usually surrounded by a gravel filter to prevent the inflow of sediments.

Figure 7. Open drain constructed by dragline. On the right side, note the water-table line and salt deposits.

Figure 8. Materials commonly used for subsurface drains. Left to right: perforated plastic pipe, clay tile (two sizes), concrete tile, and bell and spigot sewer tile.

Figure 9. Tile drain outlet.

Subsurface drains, when correctly installed, are comparatively permanent, and need little maintenance. They do not waste land or interfere with farm operations. On the other hand, they usually cost more initially than open drains and in some cases, as in impermeable soils, they may not be effective.

Clay tile is usually made in 1- and 2-foot lengths and has an inside diameter of 4 to 10 inches (Figure 8). It normally has square-cut ends. Concrete tile may come in longer lengths. Where sulfate salts are present in the soil and concrete tile is to be used, the tile should be made with sulfate-resistant cement. Clay tile is not affected by sulfate salts. Both types of tile may have fitted ends and be perforated for better entry of water. All drain tile should meet specifications of the American Society for Testing Materials (ASTM).

Bituminous-fiber or tar-impregnated pipe, perforated for drainage purposes, is suitable where surface loads are heavy. Corrugated metal pipe is used for special purposes such as in traversing high embankments or roadways. Culvert pipe of small diameter is also used for tile outlets. Perforated plastic pipe or tubing installed with a mole plow or placed in a narrow open trench and covered may be used to stabilize subsurface channels. The extensive use of metal or plastic pipe is limited by the cost and availability of the material.

Design — The design of a subsurface drainage system includes layout of drain tiles, selection of a suitable outlet, depth, spacing, selection of the tile grade, size, and the design of appurtenances or accessories.

For uniform drainage of large flat areas, a system with a main line and uniformly spaced laterals emptying into it is common. Where drainage is localized, drains may be placed merely to follow depressions on the ground surface without regard to a particular pattern or system. Interceptor drains follow along the base of a slope and intercept groundwater as it flows down the slope.

Tile drains usually discharge directly into an open ditch (Figure 9). The end of the discharge pipe should be at least a foot above the normal water surface. Tile outlets may be submerged for short periods without serious damage. Where an open drain ditch does not provide a satisfactory outlet, a pump outlet must be provided.

Fig. 9 near here

The depth of tile drains depends mainly on soil conditions. If possible, place the drains in the water-bearing strata. Where there is a rather impermeable layer of subsoil, place the soil on or above it. On irrigated lands, place it deeper than 5 feet where possible. But where extra leachings can be used to control salinity in the root zone, shallower drains may give excellent results.

The spacing between tile lines depends on the soil texture and the depth of the tile. Because water moves more rapidly through sandy soils than through clay soils, tile may be placed deeper and farther apart in lighter soils. In an irrigated area, the tile drains may have to be placed 75 to 300 feet apart in clay soils and 330 to 660 feet apart in sandy soils. Where soil texture is not a reliable guide to hydraulic conductivity, wide spacings may be adopted on a trial basis and additional laterals installed when necessary. Soils so impermeable that drains closer than 75 feet are needed are usually impractical to drain because of the high costs involved.

Tile slopes, or grades, are closely controlled by the relative elevation of the land surface. The grades commonly used are between 0.1 and 0.5

Figure 10. Tile drain installation by trenching machine.

percent. Tile on flatter grades must be laid accurately to avoid deposition of sand or silt and clogging of the line. With grades steeper than 2 or 3 percent, drain water may move along the exterior of the tile and cause cavitation. Changes in grade should be kept to a minimum. When possible, it is always better to increase grade than to decrease it. Manholes, or sandtraps, may be used to reduce grade and velocity.

For farm drainage, tile 4 and 6 inches in diameter is commonly used. For main lines, 6- and 8-inch tile is usually large enough. It is generally good practice to design for less than full flow. Also, the problems of maintaining

grade and alignment and the possibility of unavoidable settling encourage the use of larger tile.

Sandtraps catch and retain silt entering a tile line. They also offer a convenient point for inspection and maintenance. Have the bottom of the sandtrap at least 1½ feet below the flow line of the outlet tile. The incoming tile should always be higher than the outlet tile.

Manholes, or sandtraps, may consist of either corrugated steel culvert or concrete pipe 30 to 36 inches in diameter. The floor may be concrete for better stability. Provide a cover for the top and lock it for protection.

Blind inlets or French drains may be useful for removing small amounts of surface water impounded over a tile line. They are constructed by filling a section of tile trench with gravel or crushed rock. Their useful life may be only a few years, but they are economical and are easy to replace.

Installation — The installation of tile drains includes digging the trench to an established grade, laying the tile, and backfilling. Trenching machines (Figure 10), backhoes, and draglines are the machines commonly used for excavating the trench.

Always begin the excavation at the outlet end. The tile laying should follow the trench excavation closely. Place the tile as close together as possible. Roughness at the joints always allows enough space for water to enter. Cover the upper part of the tile with a strip of tar paper, fiberglass, burlap, or other similar material before covering it with gravel. It is often desirable to protect the covered tile with topsoil (blinding) from the top of the trench. The rest of the backfill may then be pushed into the trench with a bulldozer or other means without disturbing the tile.

Some trenching machines have a steel shield or shoe behind the cutting wheel large enough for a man to sit in and lay tiles as they come down a chute. Some machines have a hydraulic ram to force the tile together. Other machines are equipped to lay the tile automatically in the trench and to place

Figure 11. Tile drain being laid under adverse conditions.

a gravel envelope around the tile. Some machines are fitted with special devices that blind and backfill as the trench is being dug.

Sometimes soil conditions (Figure 11) make it impossible to lay tile in a narrow trench. You must then use a dragline and dig a wide trench with sloping sides. Where bedding conditions are especially poor, you may have to place the tile on wooden cradles, sod, or a thick bed of gravel. Sometimes second-grade sewer tile with loose joints or metal pipe is useful in unstable soils.

Cost — Cost of tile laying varies with the size of tile, depth of installation, type of soil, site conditions, source and cost of filter material, and the experience of the contractor. Table 3 gives the cost for tile installations on the Bow River Project, Vauxhall, Alberta. As a rough guide 40 percent may be charged to excavation and backfilling, 30 percent to labor, and 30 percent to materials such as tile, filter material, outlets, and sandtraps.

Tile drainage is not a general practice in Western Canada. Areas that could be successfully tile-drained are restricted by the cost of installation. Tile drainage is generally limited to draining low areas that are difficult to drain otherwise, to interception of seepage water, or to areas where special conditions justify the cost.

Maintenance — A tile drainage system properly designed and installed requires little maintenance. Keep the outlet ditch free of sediment and protect the tile outlet against erosion and undermining. Inspect and clean out the sandtraps once or twice a year.

If a tile becomes filled with sediment or roots, uncover the line at some point downstream to locate the obstruction. If the line is not completely clogged and water is available, the sediment may sometimes be flushed out. Use a suitable plug, swab, or sewer rod to remove the blockage. It is often more economical to replace the entire plugged section.

Tree roots only become troublesome when proper precautions have not been taken. Remove brush and trees such as willows, poplar, and

TABLE 3. UNIT COSTS OF TILE DRAIN INSTALLATIONS, 1951-1963

Year	Size inches	Depth[1]	Length feet	Unit cost per foot $	Remarks[2]
1951	6	Deep	10,550	1.84	H — B
1952	6	Deep	3,375	1.76	H — B
	6, 8	Deep	3,160	1.11	M — T
	6	Deep	2,930	1.43	M,H — B,T
1953	8	Deep	11,080	1.46	H — B,D
	8, 10	Deep	9,035	1.41	M — T
	8	Deep	5,750	1.78	M,H — B,T
1954	6, 8, 10	Deep	38,100	1.07	H — B,D
1955	8, 10	Deep	31,500	1.59	M,H — B,T,D
1957	4	Shallow	1,375	.63	H — B
1958	4	Deep, shallow	6,260	.60	H — B
1959	8	Deep	2,625	.90	H — B
1963	4	Shallow	1,480	.54	H — B

[1] Deep, 5 to 10 feet; shallow, 3 to 4 feet.
[2] H, hand-laid tile; M, machine-laid tile; B, backhoe excavator; D, dragline excavator; T, trencher.

Figure 12. Pumped drainage well.

cottonwoods growing within 100 feet of a tile line. Where it is impractical to remove the vegetation, install sealed bell and spigot tile, tar-impregnated pipe, or metal pipe. When tile lines become filled with roots, it is best to dig up and replace the clogged section and remove the troublesome trees at the same time.

Pump Drainage

Where soils are underlain by porous aquifers, it is often possible to lower the water table over large areas by pumping (Figure 12). To find out whether the pumping would be effective, drill test wells and pump them. Determine the area of influence by measuring water levels in adjacent observation wells or piezometers. Spacing, depth, and capacity of the pumped wells and other operational details may be determined from these tests.

Pumped drainage water may be used for irrigation if the quality is acceptable. The value of the water nearly always offsets the pumping costs. Poor-quality water may sometimes be mixed with better-quality water to provide a supplemental irrigation supply.

RECLAMATION MEASURES

In any reclamation program, the first essential is to provide good drainage. The water table must be maintained at a depth below the root zone of the crop to keep the upward movement of salts from the groundwater at a minimum. The optimum depth for any given locality varies

with the climate, the soil characteristics, and the type of crops grown. If an adequate water-table depth cannot be maintained, irrigation and management practices may sometimes be altered to sustain crop production.

Leaching by percolation of water through the soil profile may be either a natural or an artificial process. Good subsurface drainage is absolutely necessary. Where drainage is inadequate, water applied for leaching may cause the water table to rise and aggravate the salt problem.

Leaching is most effective when it is possible to pond water over the entire surface. This may require expensive and extensive land preparation unless the land is rather flat. Where the land is sloping, a contour dike system or a border dike system with cross dikes down the slope will provide effective leaching at a small percentage of the cost of preparing level basins. It is best to apply the leaching water as successive floodings or rinsings rather than continuous ponding. Good soil and water management is essential after leaching to assure successful reclamation.

Moderately effective leaching can be accomplished through excess irrigation. The leaching may be done at any time it does not interfere with other operations. It is often convenient to leach in the fall (i.e., fall irrigation) when water is plentiful. Water-table and drainage conditions then may be more favorable than during the regular irrigation season.

In most affected areas, some form of subsurface drainage will eventually be required. As the acreage of specialty crops increases, the more intensive irrigations that are needed by these crops are causing the water tables to rise. Conditions of waterlogging and soil salinity brought about by the rising water tables are becoming serious. This means that drainage installations will be needed on the farm. Up to now drainage systems have been installed by irrigation projects or districts. Very few irrigation farmers have installed drainage systems on their own farms. As knowledge and techniques improve through research, drainage systems and reclamation measures for irrigation farmers in Western Canada should become economically feasible.

DEFINITION OF TERMS

Alkaline soil — Any soil that has a pH greater than 7.0.

Aquifer — An underground water-bearing formation of permeable rock, sand, or gravel.

Capillarity — The action by which water in the small pores of the soil is elevated and held by surface tension.

Dispersion — The process whereby compound particles are broken into component particles. Sodium tends to disperse clay particles into finer particles, which move downward in the soil.

Drainage — As a practice, the process of removing excess ground or surface water by artificial means.

Groundwater — Water in the soil below the water table.

Infiltration rate — The maximum rate at which water enters the soil under specific conditions, including an excess of water.

Leaching — The process of removing soluble salts from the soil by passage of water through the soil.

Observation well — A well for determining the level of a water table. It is usually an open hole cased with a perforated pipe.

Percolation — The downward movement of water through the soil.

Permeability — The ease with which gases, liquids, or plant roots penetrate or pass through a soil.

pH — The degree of acidity or alkalinity of a soil as determined by means of a glass electrode or other suitable electrode or indicator at a specified soil-to-water ratio and expressed in terms of the pH scale.

Piezometer — An open-ended pipe driven into the soil to measure the soil-water pressure at the end of the pipe.

Reclamation — For saline or alkali soils, the process of removing excess soluble salts or excess exchangeable sodium.

Saline soil — a nonsodic soil containing enough soluble salts to impair its productivity. The term "white alkali" has often been used in error to indicate a saline soil.

Saline-sodic soil — A soil that contains enough exchangeable sodium to interfere with the growth of most crops and also appreciable quantities of soluble salts. The exchangeable sodium is greater than 15 percent of the cation exchange capacity, the conductivity of the saturation extract is greater than 4 mmhos/cm, and pH is usually 8.5 or less in the saturated soil paste.

Salinization — The process of accumulation of salts in soil.

Saturation extract — Water extracted from a soil-water mixture, which filled all the spaces between the soil particles.

Seepage — The slow movement of water into, through, or from soil.

Sodic soil — A soil that is highly alkaline (pH 8.5 or higher) or has a high exchangeable sodium content (15 per cent of the cation exchange capacity or higher) and a low conductivity of the saturation extract.

Sodium adsorption ratio (SAR) — A ratio for soil extracts and irrigation waters used to express the relative activity of sodium in exchange reactions with soil.

Solonetzic soils — Soils with a thin, friable surface layer underlain by a dark, hard, columnar layer usually high in sodium; formed under arid semi-arid, and subhumid climates.

Waterlogged — A soil condition where a high water table is detrimental to plant growth; the replacement of most of the soil air by water.

Water table — The upper surface of groundwater or that level below which the soil is saturated with water; the elevation at which water stands in a hole dug down to the water table. A perched water table is a local water table formed above and separated from the main water table, usually by a slowly permeable subsoil layer. It may be either a temporary or a permanent water table.

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